

# **HPRF System**

Klystron

Circulator

Waveguide

Window

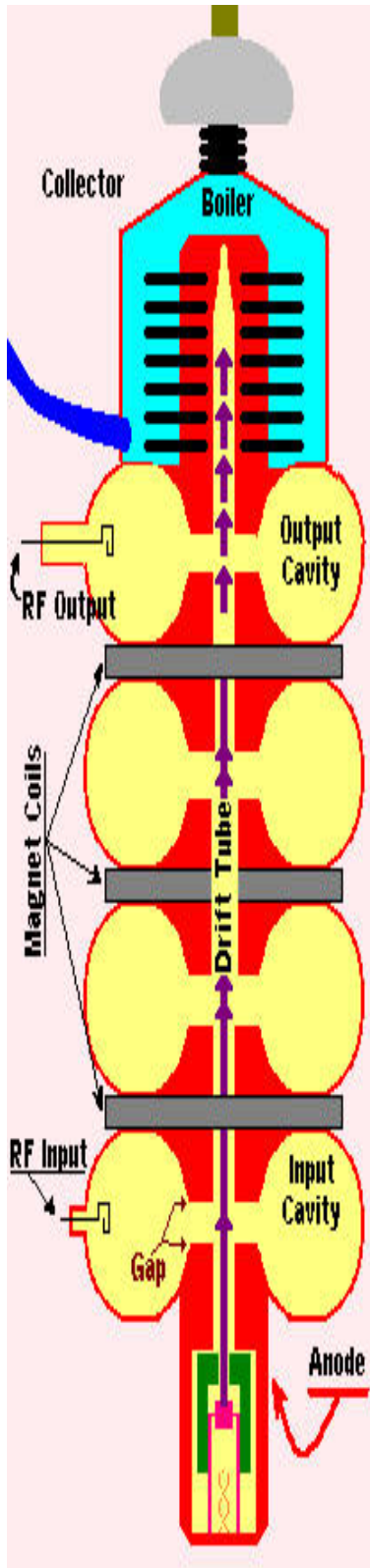
Transmitter

# Klystron



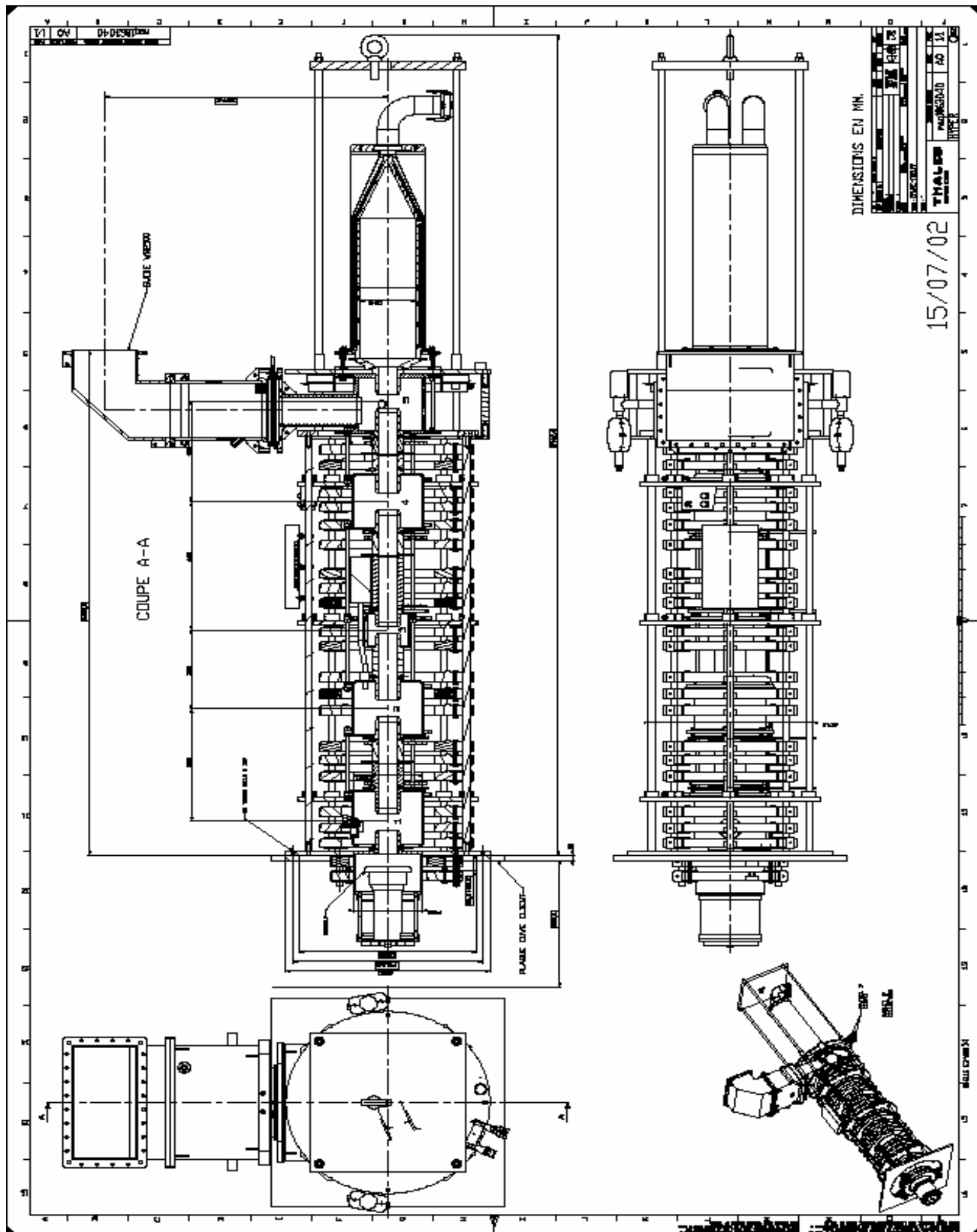
- Invented in 1939 at Stanford by William Hansen and brothers Russell and Sigurd Varian
- kly·stron - An electron tube used to amplify or generate ultrahigh frequency by means of velocity modulation
- Greek kluzein, klus-, to wash, break over + -tron.

# Inside the Klystron



- Cathode produces electrons.
- Voltage pulse from anode to cathode accelerates electrons.
- Magnets are used to focus the electron beam
- Cavities velocity modulate the electron beam
- Output cavity, or ultimate cavity, is coupled to the transmission line
- 5 Cavities is common.
- Cavities tuned to different frequencies to provide required bandwidth.
- Collector must absorb the high energy electrons – must be cooled! Collector must absorb power not removed in the output cavity. Many varieties of collectors exist to dissipate the high heat load of the electrons.

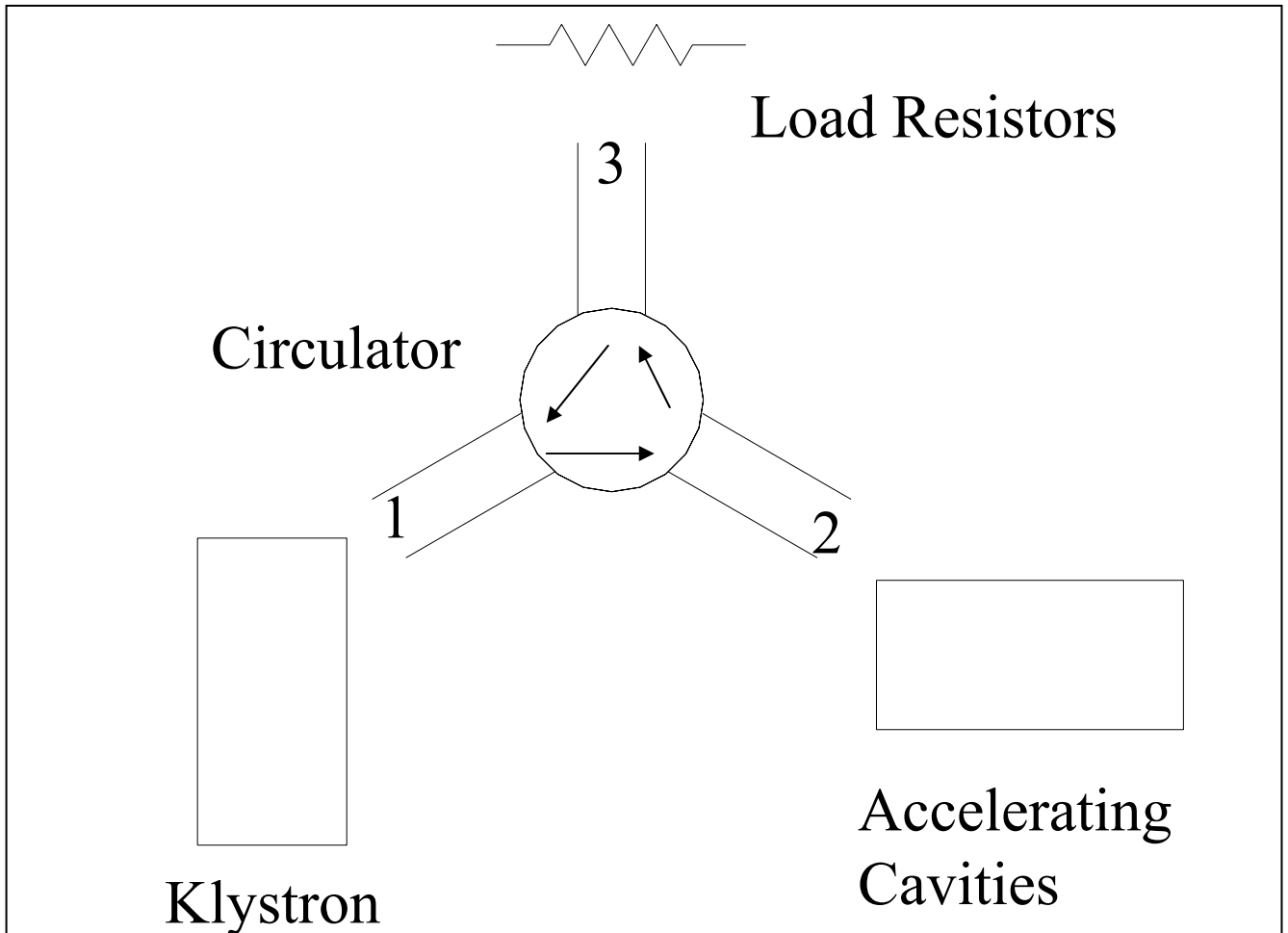
# Thales 402.5 MHz Tube



# More About Klystrons

- Internally, the Klystron has a vacuum, and therefore a window must exist to take the energy from the vacuum environment to the desired load.
- Reflections from the load can cause the window to arc and then break.
- Circulators are used to protect against this from occurring

# Circulators Protect the Klystron



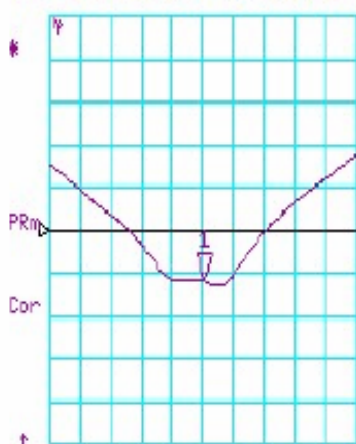
# Circulator S-parameters

**402.5 MHz Circulator Test S/N 964583 September 18, 2001**

**At ~30°C water temp**

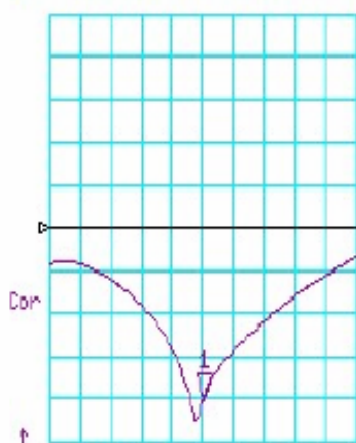
18 Sep 2001 12:48:15

CH1 LOG 10 dB/ REF -20 dB  
S11 1:-31.760 dB 402.500 002 MHz



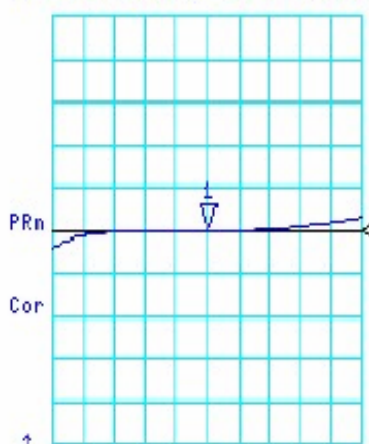
START 377.500 MHz STOP 427.500 MHz

CH3 LOG 10 dB/ REF 0 dB  
S12 1:-40.585 dB 402.500 002 MHz



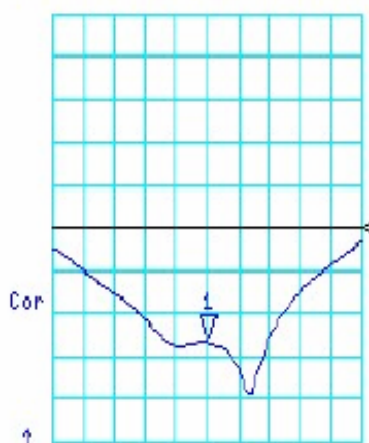
START 377.500 MHz STOP 427.500 MHz

CH2 LOG 10 dB/ REF 0 dB  
S21 1:-14.250 dB 402.500 002 MHz



START 377.500 MHz STOP 427.500 MHz

CH4 LOG 10 dB/ REF 0 dB  
S22 1:-25.994 dB 402.500 002 MHz



START 377.500 MHz STOP 427.500 MHz

# Connecting It Together

- SNS uses rectangular waveguide.
- Rectangular waveguides are usually operated in the  $TE_{1,0}$  mode for energy propagation.
- The  $TE_{1,0}$  mode has less loss than coaxial cable (less conductors to carry the current).

# Transmitter Description

## SECTION 2.0

### TRANSMITTER SYSTEM DESCRIPTION & INSTALLATION

This section provides an overall description of the Transmitter and gives the procedures required for its proper installation at the user's facility.

#### 2.1 SYSTEM DESCRIPTION

The Transmitter consists of three major components as shown in Figure 2-1.

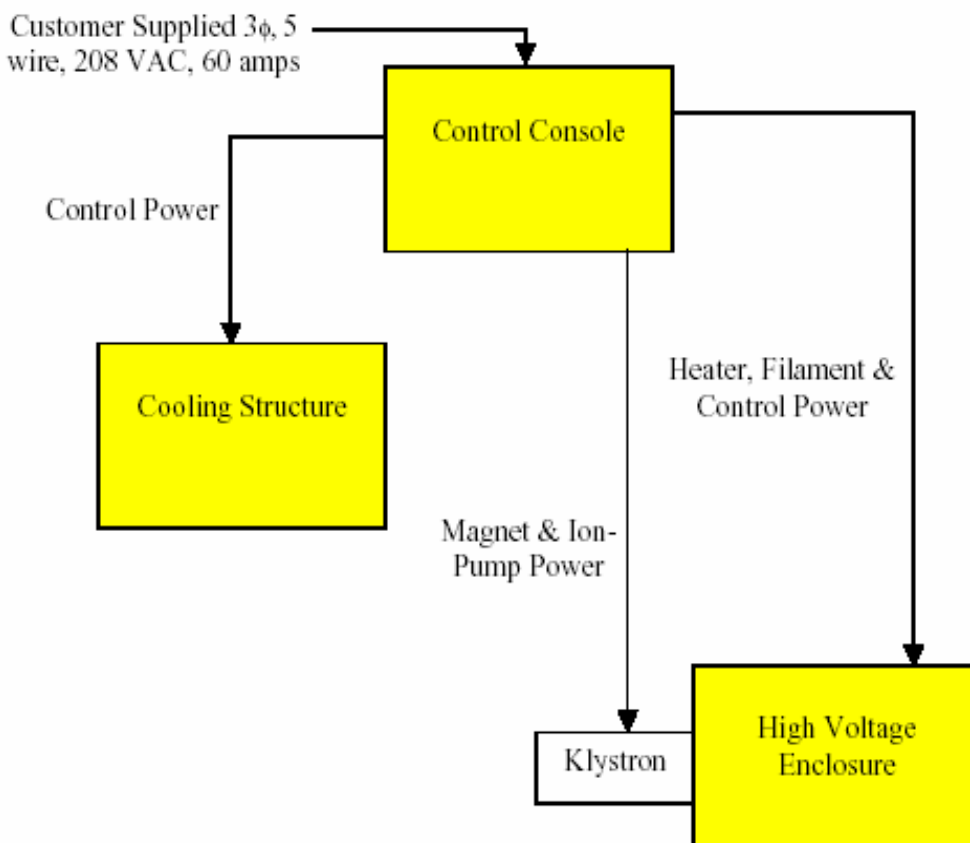


Figure 2-1. Transmitter Block Diagram, Showing Power Connections.

The Transmitter will provide: amplified low level RF power, magnet power, Vac-ion pump power and filament power to the klystron. It will measure the klystron's cathode beam current provided by the high voltage power supply, monitor the RF delivered to the klystron's input port and the power at the directional coupler at the klystron output. It will monitor the temperatures and flows of the cooling fluids for the klystron, high power circulator and its load, and the klystron and accelerator window, and use these flows and temperatures to calculate dissipation. It will interface with the SNS central control system to provide a means of local and remote klystron control and status, protection for the klystron and its ancillary power supplies, and personnel safety (See Specifications, Section 9).

The High Voltage Enclosure (HVE), shown in Figure 2-2, provides physical support for the klystron and oil insulation for the high voltage power supply connection to the cathode. The HVE is instrumented to measure and provide an over-current threshold for the klystron cathode current. In the event of a klystron cathode over-current, it sends a crowbar signal, within one microsecond, to the High Voltage Power Supply and removes the “Ready for High Voltage” signal.

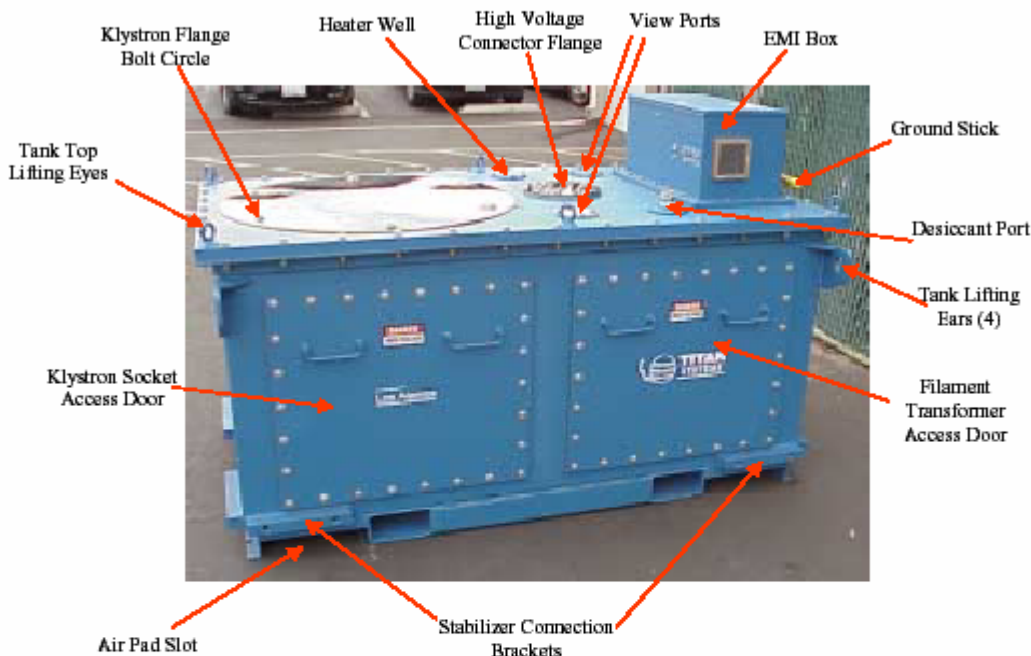


Figure 2-2. High Voltage Enclosure.

Additional instrumentation and control, in the HVE, monitor oil temperature and level, keeps the oil warm in the event the filament is turned off, monitors interlocks at the grounding stick, klystron socket, HVE doors, tank cover, and the high voltage power supply connector flange. The HVE is moved using two air pads placed in the slots at the ends of the tank. The Stabilizers (Figure 2-6) can be connected to the base of the tank to prevent tipping while it is in motion. Lifting eyes provided on the tank top are for lifting the *lid only; not the klystron and lid*, or for connecting guy wires to the klystron. If the whole tank is to be lifted the lifting ears should be used.

The 402.5 MHz Cooling Structure (CS), shown in Figure 2-3, monitors the liquid coolant temperatures before and after the coolant enters the klystron collector and body circuits, high power circulator and its load and the accelerator window (remotely). It also measures the flow rates in each of these circuits. The flows and temperatures are then used to calculate dissipation at the heat loads. There is a separate liquid cooling circuit for the Circulator Load, which uses a glycol/water mixture. The 805 MHz CS uses water to cool the circulator load.

In this case there is only a water manifold. Air-flow for cooling the Klystron window is provided by a 80 cfm pressure blower. The CS is an open frame structure, which can be connected to the major facility coolant supply pipes near each klystron station. It is easily moved using the air pads or via user supplied lifting eyes, screwed into threaded holes located in the top of the frame.

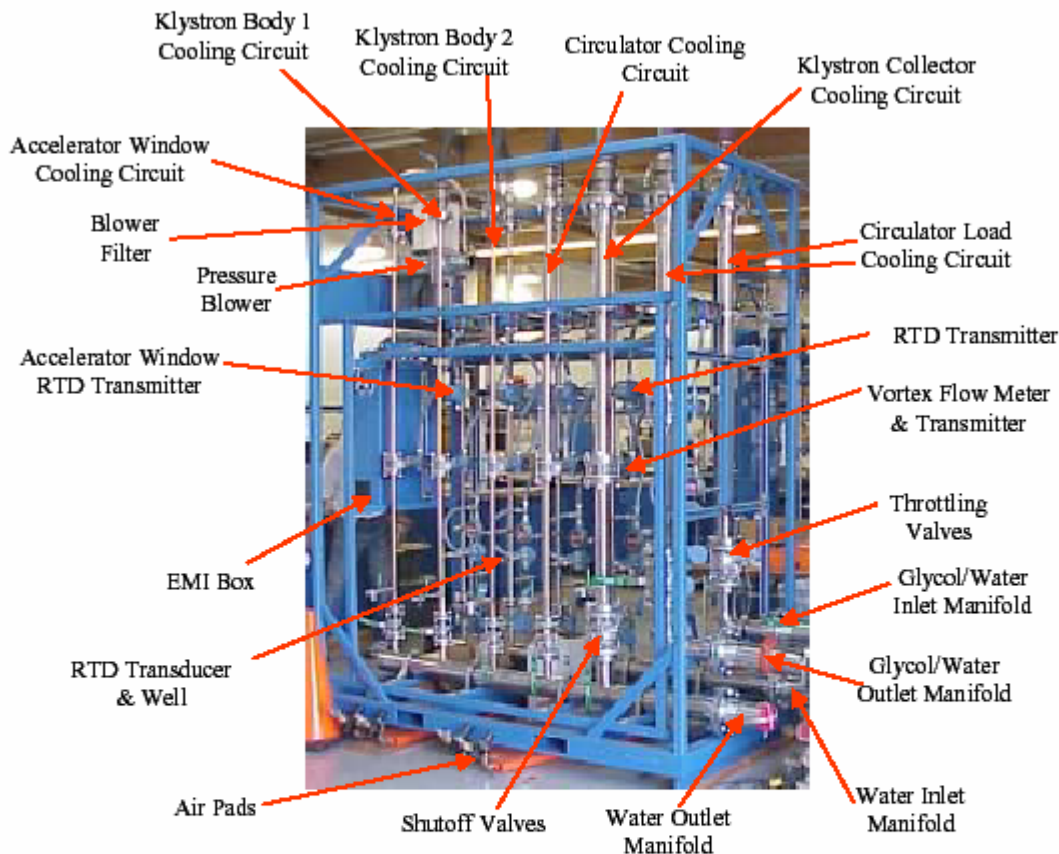


Figure 2-3. 402.5 MHz Cooling Structure.

The Control Console (CC), shown in Figures 2-4 and 2-5, contains all the klystron's ancillary power supplies and the Solid State RF Amplifier Chassis as well as a Programmable Logic Controller with attached User Monitor. The PLC acts as an interface for local and remote control and monitoring of the klystron and ancillary power supplies. All ancillary power supply chassis are clearly shown in Figures 2-4 and 2-5. The CC is vented by two blowers, which are mounted in the bottom of each rack. The Control Power Chassis provides low voltage DC to the CC and the AC Distribution Chassis contains breakers for the distribution feeders, which route AC power to all the chassis in the CC. The PSS Chassis contains all the timing monitoring and sampling circuits, the hardwired safety system, communication connections between the CC and the HVE and logic for all customer-connected interlocks. The PLC and PSS Chassis communicate with one another and together provide the control

and monitoring functions for the Transmitter. The CS transmits all temperature and flow data to the PLC directly.

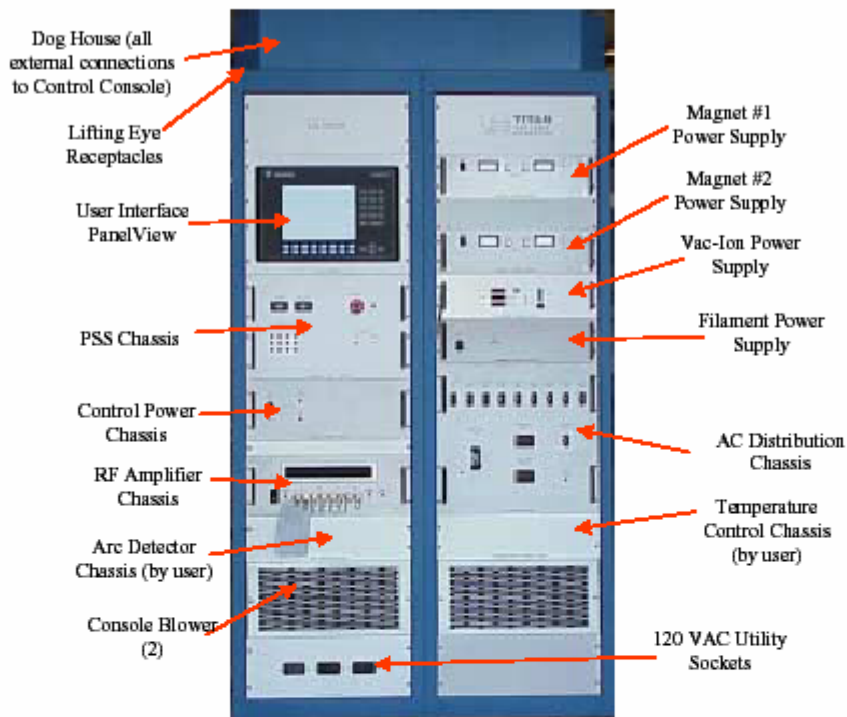


Figure 2-4. Control Console, Front.

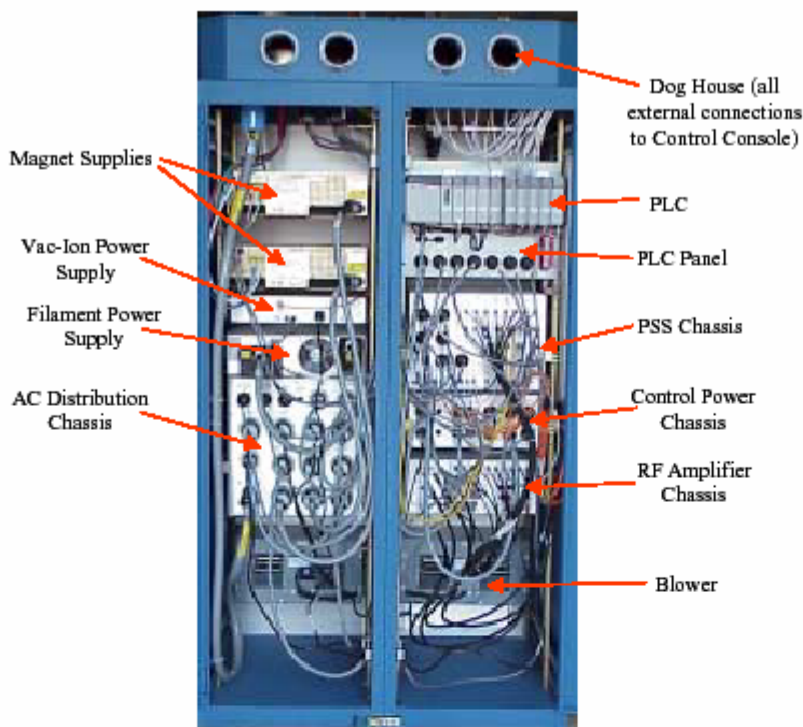


Figure 2-5. Control Console, Rear.

User supplied lifting eyes which can be screwed into threaded holes at the top corners of the CC are used to facilitate moving. All external electrical and fiber optic cables will be routed through conduits, installed by the user and connected to the Dog House, atop the CC via the conduit connectors (see Figures 2-8 and 2-9).

The connectors on the external cables and optical fibers will be connected to feed-throughs in the floor of the Dog House, which in turn are connected, via internal cabling, to the various chassis in the CC.

## 2.2 MECHANICAL INSTALLATION

The three major components, Cooling Structure (2900 pounds), High Voltage Enclosure (3300 pounds/without oil) and Control Console (1150 pounds) should each be placed in their appropriate positions in the Accelerator's Klystron Gallery. The CS and HVE should be *bolted to the floor*, using slots provided in the bottom end channels, before any pipes are connected to the CS or klystron installed in the HVE.

The user is strongly encouraged to use the Stabilizers, shown in Figure 2-6, while moving the HVE with installed klystron. Connect the Stabilizers so that they protrude in the direction of



# Transmitter Operations

## SECTION 3.0 OPERATING PROCEDURES

### 3.1 LOCAL CONTROL

#### 3.1.1 Startup

The procedure described in Section 2.4 can be used for starting up the Transmitter. Details on Modes and the PanelView Screens is given below.

#### 3.1.2 Modes

The Modes of the Transmitter are a sequence of states that are entered on the way to the state in which the klystron will be ready for the application of high voltage. These modes offer a step-by-step logical and organized procedure for turning on the Klystron amplifier (see Figure 3-1).

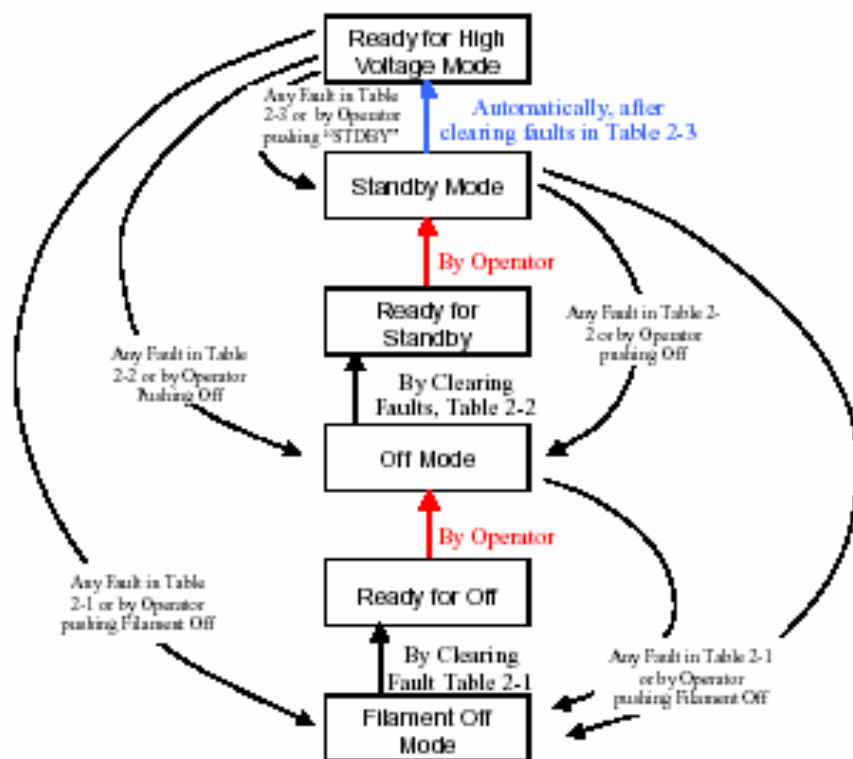


Figure 3-1. Hierarchy of Modes.

These modes also serve as stopping points that, after a fault occurs, allow the Transmitter to shut off only those power supplies required to prevent damage to the equipment due to the fault, but not those that there is no need to shut off. For example, if a magnet power supply

current drops below one of the thresholds, resulting in loss of control of the electron beam, the high voltage must be removed. But, as long as the vacuum is maintained there is no need of removing the filament power. Thus, if such a fault occurs, the Transmitter transfers to “Standby” from “Ready for High Voltage,” a mode in which the high voltage is removed but the filament stays on. In “Standby” the operator can assess the magnet power supply problem, possibly fix it and return the Transmitter to operation, with minimum interference with accelerator operation.

The “Filament Off” mode is defined as the operational mode in which all AC power is removed from all components except the PLC, Panelview, Vac-ion Power Supply and High Voltage Enclosure oil heater. To get to the “Off” mode from “Filament Off” the operator must push “Off” after the “Ready for Off” indication is given by the mode status indicator on any of the PanelView screens.

The “Off” mode is one step above the “Filament Off” mode in which AC Power is applied only to the PLC, Panelview, Vac-ion Power Supply and filament. This is the mode the Transmitter should be left in if RF power is not going to be required for a long period of time, but the filament is to be kept energized. This mode can be entered only from the “Filament Off” mode after the faults listed in Table 2-1 have been cleared. When all of these faults are cleared the PanelView indicates “Ready for Off” and the operator then pushes the “Off” button (see Figure 2-17) to get to “Off.” This is the mode in which the filament is warming up. To get to the “Standby” mode from “Off” the operator must push “STDBY” after the “Ready for Standby” indication is given by the mode status indicator on any of the PanelView screens.

The “Standby” mode is the period in which all the subsystems, except the filament power supply, are turning on and warming up. This is the time to make sure the Magnet Supply currents and voltages are set properly. The Cooling Cart Blower should also be on. Once all subsystems are at normal levels and no faults are detected, the Transmitter should automatically enter the “Ready for High Voltage Mode.”

Tables 2-1, 2-2 and 2-3 of Section 2.4 show the Transmitter faults grouped by the Mode to which the Transmitter is returned when the fault occurs and which must be cleared before being allowed to transfer to the next higher mode (see Figure 3-1).

The operator may transfer to any lower mode at any time by pressing any of the three buttons; “STDBY” “OFF,” or “FIL OFF” just below the mode status indicator on any of the Status and Control Screens (see Figures 3-1 through 3-8). If “STDBY” is pressed while in “Ready for High Voltage,” the indicator will immediately cycle back to “Ready for High Voltage” but the Transmitter will not leave “Ready for High Voltage.”

### **3.1.3 PanelView Screens**

Figures of all PanelView (User Interface) screens are shown in this section, along with short descriptions of the data available and controls that can be invoked with each one. These

screens can be classified in three groups; “Status & Control Screens,” “Limits Screens” and “Constants Screens.” All together there are 21 screens.

### 3.1.3.1 Status & Control Screens

Status and Control Screens provide current information on the status of every interlock and allow the operator control the modes (see Section 3.1.2). They show the current values of all monitored power supply currents and voltages, coolant flow and dissipated and RF power, as well as the associated threshold values for producing faults.

#### 3.1.3.1.1 Main Screen

The Main Screen is shown in Figure 3-2. The screen shows current time and date. It shows the present values of the Magnet, Filament Vac-ion and Cathode Power Supply currents and present values of the Klystron Amplifier drive and output RF power.

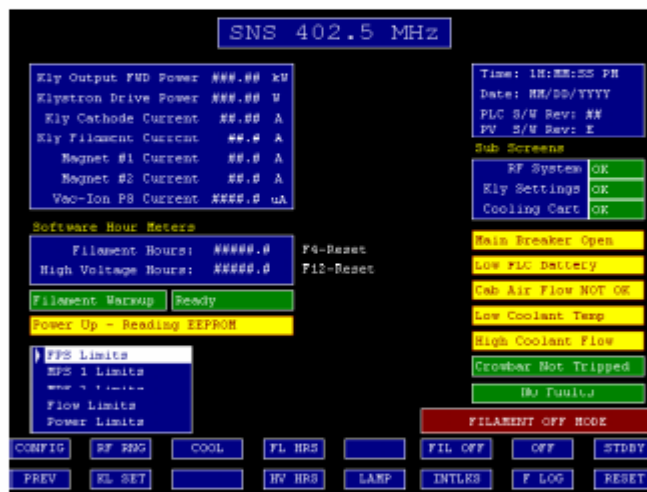


Figure 3-2. PanelView Main Screen. The SNS 402.5 MHz label will show as 805 MHz when operating an 805 MHz Transmitter.

Its Sub Screens displayed in the upper right quadrant of the Main Screen shows whether any of the thresholds on the three sub-screens (Figures 3-3, 3-4, 3-5) has been exceeded.

There is an hour display for the Klystron’s cumulative filament and electron beam operating time, a “filament warm-up time remaining” indication and indications for the Main Breaker, PLC Battery and Control Console Cabinet Air Flow, Summary of Coolant Temperature, and Summary of Coolant Flow.

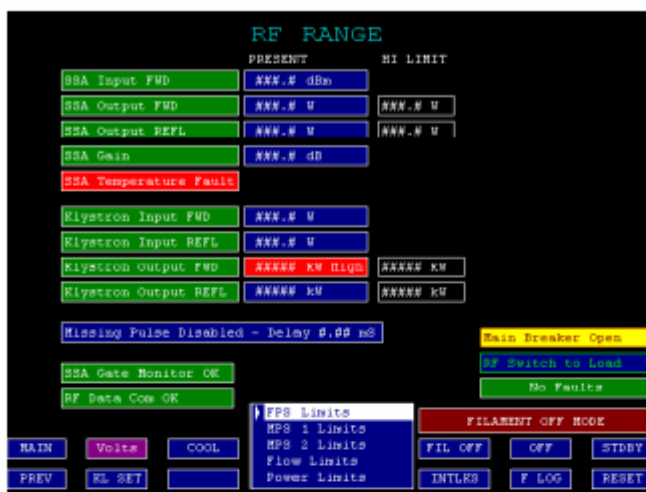


Figure 3-3. PanelView RF Range Screen.

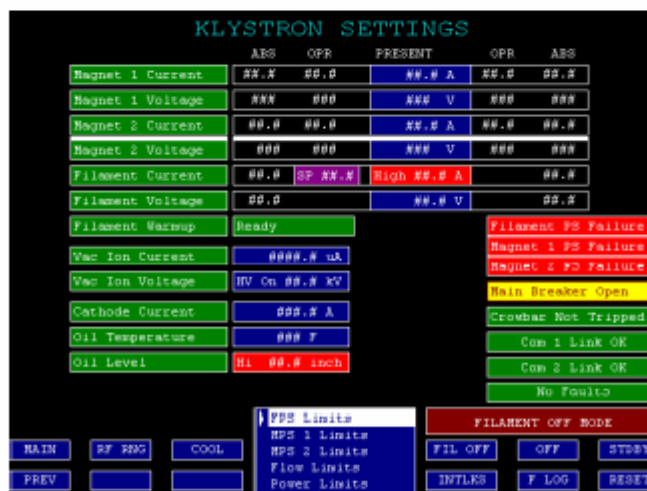


Figure 3-4. PanelView Klystron Settings Screen.

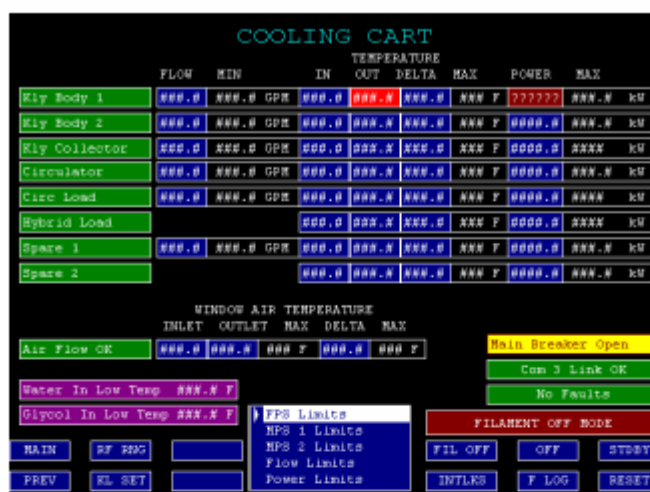


Figure 3-5. PanelView Cooling Cart Settings Screen.

Any Status Screen can be displayed from any other Status Screen by pressing the Function Keys as shown in Table 3-1. The exception is the Communication Faults Screen, which can only be accessed when the Interlocks Screen is being displayed.

Table 3-1. Status Screens.

To Display:	Press the Function Key:	Function Key Identification Indicator:
Main Screen*	(F1)	"MAIN"
RF Range Screen	(F2)	"RF RNG"
Klystron Settings Screen	(F10)	"KL SET"
Cooling Screen	(F3)	"COOL"
Interlocks Screen	(F14)	"INTLKS"
Fault Log Screen	(F15)	"F LOG"
Communication Faults**	(F4)	"COM"

\* When the Main Screen is displayed, pressing (F1) displays the Configuration Screen. This screen allows configuration of communications, selecting preset operations, obtaining terminal information, setting up the screen, and setting up a printer (see Section 4.1.5 for details).

\*\* This screen can only be displayed from the Interlocks Screen.

### ***3.1.3.1.2 RF Range Screen***

The RF Range Screen is one of the three sub screens to the Main Screen and shows the present values and trip points for all measured RF powers and the RF Gain. It also shows whether the missing pulse detector is active or not. The SSA Gate Monitor produces a fault if the gate pulse received by the RF Amplifier does not make a transition from low to high each time a timing signal is sent to the Transmitter.

### ***3.1.3.1.3 Klystron Settings Screen***

The Klystron Settings Screen, the second sub screen, shows all the current and voltage thresholds, present values, trip levels, and trip indications for the Magnet, Filament (as well as the filament set point), and Vac-ion power supplies. It also shows the oil temperature and level in the High Voltage Enclosure and the magnitude of the klystron's pulsed cathode current.

### ***3.1.3.1.4 Cooling Cart Screen***

The Cooling Cart Screen, the third sub screen, shows all the thresholds, present values, trip levels, and trip indications for the cooling fluid temperatures, flow rates and dissipated power for the monitored cooling circuits.

In addition, klystron window inlet and outlet cooling air temperatures are shown as well as the inlet manifold temperatures for the cooling water and water/glycol mixture.

### ***3.1.3.1.5 Interlocks Screen (and Communications Faults Screen)***

The status of all Interlocks is shown on the Interlocks Screen in Figure 3-6. This includes External PSS interlocks, External Fiber Optic interlocks, External Standby interlocks, "Ready for High Voltage" interlocks, Cabinet access, 24 volt power supply voltage, PSS power, the HVE access, H V cable, ground stick and klystron socket, and the status of the five communication links.

Details of the communications faults are shown on the Communications Faults Screen (Figure 3-7), which can only be accessed from the Interlocks Screen.

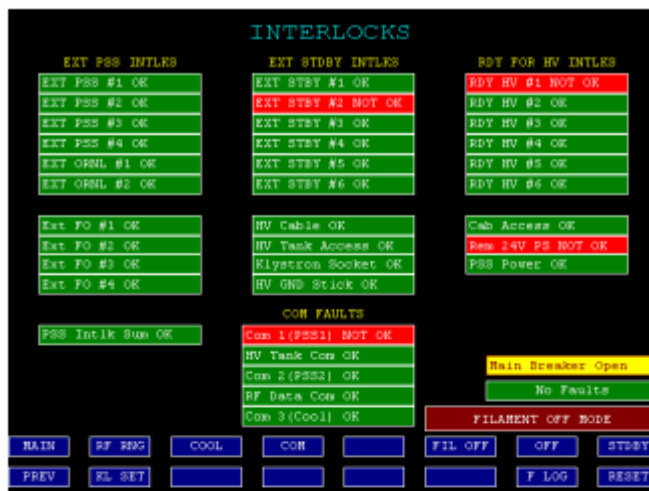


Figure 3-6. PanelView Interlocks Screen.

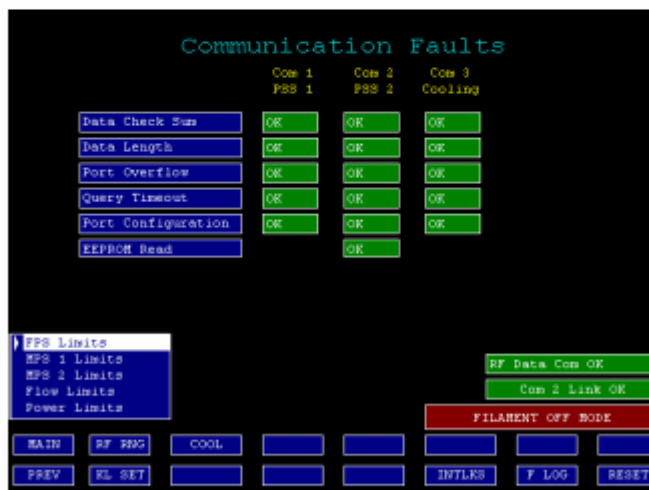


Figure 3-7. PanelView Communications Faults Screen.

### 3.1.3.1.6 Fault Log Screen

The Fault log screen (Figure 3-8) logs all faults and labels those with an “FF” that occurred first in a sequence of multiple faults.



Figure 3-8. PanelView Fault Log Screen.

### 3.1.3.2 Limits Screens

The Limits Screens (Filaments Power Supply Limits- Figure 3-9, Magnet Power Supply Limits #1 & #2 – Figures 3-10 and 3-11, Coolant Flow Limits – Figure 3-12, Dissipated Power Limits – Figure 3-13, Temperature Limits – Figure 3-14, RF Amplifier Limits – Figure 3-15, and Miscellaneous Limits – Figure 3-16) allow the operator to change any of the current, voltage, power, temperature, etc., fault thresholds; change the filament current setpoint, ramp duration, warm-up and minimum warm-up time; change the RF attenuation factor for the Klystron Output power display; set the delay of the delayed sampling pulse; and enable or disable the timing pulse interval watchdog timer. These screens are classified according to the different types of limits. All the Limit Screens (as well as the “Constants Screens,” see Section 3.1.3.3) can be accessed from the Limits & Constants Menu (see Figure 2-16). The Limits & Constants Menu is located on all screens with the exception of the Interlocks Status & Fault Log Screens. Use the “Move Buttons” (see Figure 2-16) to point to the desired Limits or Constants Screen in the Limits & Constants Menu and then press the “Return Button.” After pressing “Return” a password box will appear. Enter the numeric password and press “Return,” and the appropriate limits or constants screen will be displayed. You may then change the limit or constant. You can then select other limits or constants screens without having to reenter the password. After you are through changing limits or constants, you can return to a Status Screen (except the Interlocks & Fault Log Screens) by pressing the appropriate function key. Note, that because of an insufficient number of functions keys on some of the Limits and Constants Screens, you can’t return to all Status screens directly from any Limits & Constants Screens, but since you can always return to the Main Screen from any of the Limits & Constants Screens this is not a problem. The various Limit Screens are shown in the following sections, and these may be used to locate the proper screen on which to enter a particular limit.

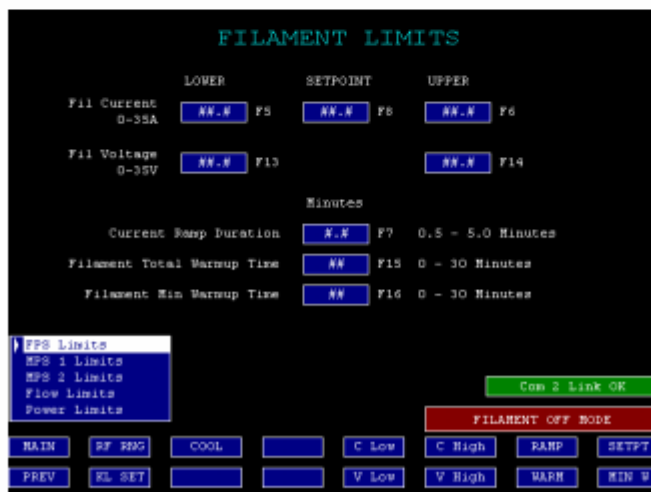


Figure 3-9. PanelView Filaments Limits Screen.





Figure 3-10. PanelView Magnet PS #1 Limits Screen.



Figure 3-11. PanelView Magnet PS #2 Limits Screen.

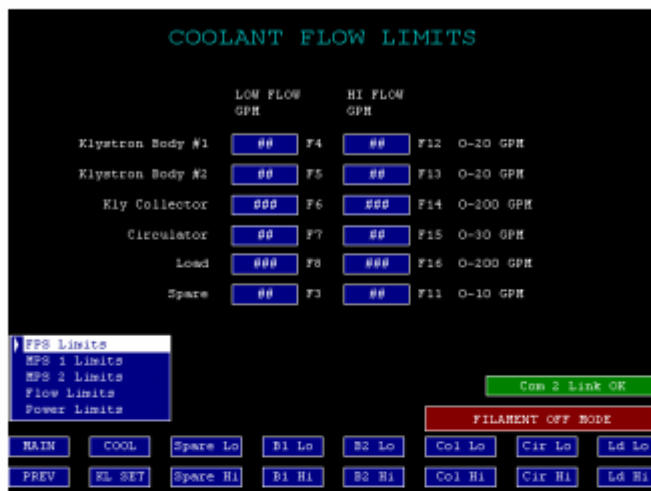


Figure 3-12. PanelView Coolant Flow Limits Screen.

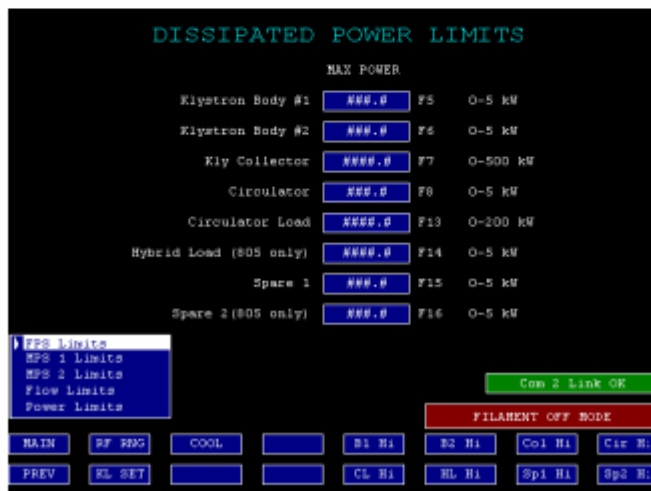


Figure 3-13. PanelView Dissipated Power Limits Screen.

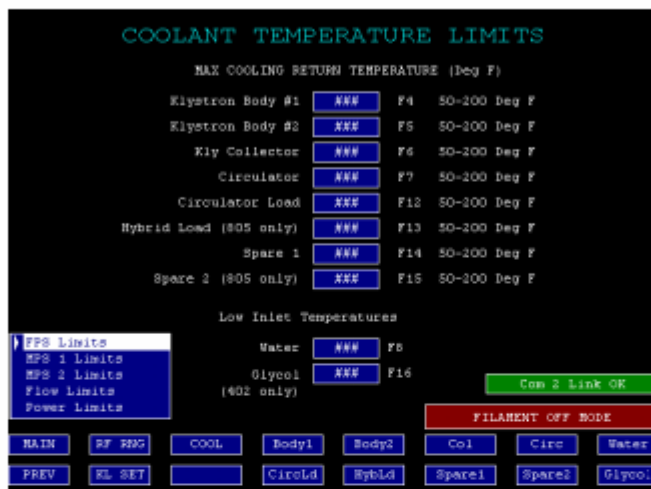


Figure 3-14. PanelView Coolant Temperature Limits Screen.

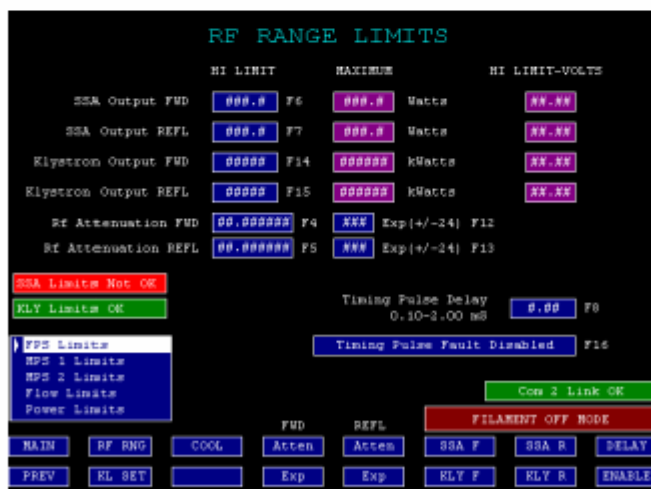


Figure 3-15. PanelView RF Range Limits Screen.



Figure 3-16. PanelView Miscellaneous Limits Screen.

### 3.1.3.3 Constants Screens

The Filament Isolation Transformer secondary (klystron filament) currents and voltages are inferred using second-degree polynomial functions, each dependent on the primary current and primary voltage. The RF power measurements displayed on the PanelView are obtained using functions dependent on the respective detector voltages in the RF Chassis. The coefficients of all these functions are determined at the factory and are entered on the appropriate “Constants Screens.” Table 3-2 lists the 6 Constants Screens.

Table 3-2. Constants Screens.

Filament Current Constants
Filament Voltage Constants
SS Amplifier Input Constants
SS Amplifier Output Constants
Klystron Input Constants
Klystron Output Constants

These screens can be accessed as described in Section 3.1.3.2. The various Constants Screens are shown in the following sections, and these figures may be used to locate the proper screen on which to enter a particular constant.

**NOTE**

*Always change RF limits right after changing RF Constants because limits are compared in the PIC and after the constants are changed, new limits must be calculated for the PIC because it does not happen automatically.*

**3.1.3.3.1 Filament Power Supply Constants**

The Filament Current Constants Screen (Figure 3-17) contains the constants in the equation used to infer the klystron filament current,  $I_F$ , from the power supply output voltage,  $V_P$ , and output current,  $I_P$ :

$$I_F = C_{10} + C_{11} V_P + C_{12} V_P^2 + C_{13} I_P + C_{14} V_P I_P + C_{15} I_P^2.$$

Table 3-3 identifies the box on the screen in which to enter each of the constants.

Table 3-3. Identification of Constants on the Filament Current Screen.

Coefficient	Current Constant	Exponent
$C_{10}$	0-F3	0-F11
$C_{11}$	1-F4	1-F12
$C_{12}$	2-F5	2-F13
$C_{13}$	3-F6	3-F14
$C_{14}$	4-F7	4-F15
$C_{15}$	5-F8	5-F16



Figure 3-17. PanelView Filament Current Constants Screen.

The Filament Voltage Constants Screen (Figure 3-18) contains the constants in the equation used to infer the klystron filament voltage,  $V_F$ , from the power supply output voltage,  $V_P$ , and output current,  $I_P$ :

$$V_F = C_{V0} + C_{V1}V_P + C_{V2}V_P^2 + C_{V3}I_P + C_{V4}V_P I_P + C_{V5}I_P^2.$$

Table 3-4 identifies the box on the screen in which to enter each of the constants.

Table 3-4. Identification of Constants on the Filament Voltage Screen.

Coefficient	Current Constant	Exponent
$C_{V0}$	0-F3	0-F11
$C_{V1}$	1-F4	1-F12
$C_{V2}$	2-F5	2-F13
$C_{V3}$	3-F6	3-F14
$C_{V4}$	4-F7	4-F15
$C_{V5}$	5-F8	5-F16



Figure 3-18. PanelView Filament Voltage Constants Screen.

## 3.1.3.3.2 RF Amplifier Constants

The RF Amplifier power measurements displayed on the PanelView are obtained using functions dependent on the appropriate detector voltages in the RF Chassis. The coefficients of these functions are determined at the factory and are entered on the appropriate "RF Amplifier Constants Screens." See Section 5.1.2 and 5.1.3 for explanations of how to calibrate the RF Chassis detectors and how to obtain the constants used for the functions.

Table 3-5 identifies which box on the RF Amplifier Constants Screens each of the constants should be entered in.

Table 3-5. Identification of Constant Entry Boxes for the RF Amplifier Constants Screens

RF Detector	Equation for RF Power	A	A exponent	B	B exponent	C	C exponent
RF Input Forward	$\text{dBm} = A + B * \text{Log}_{10}(V_D)$	F3	F11	F4	F12	-	-
RF Detector	Equation for RF Power	C	C exponent	D	D exponent	E	E exponent
Amp. Output Forward	Watts $= C + D * V_D + E * V_D^2$	F3	F11	F4	F12	F5	F13
Amp. Output Reflected	Watts $= C + D * V_D + E * V_D^2$	F6	F14	F7	F15	F8	F16



Figure 3-19. PanelView SSA Input Constants Screen.



Figure 3-20. PanelView SSA Output Constants Screen.

### 3.1.3.3.3 Klystron Constants

The RF Klystron power measurements displayed on the PanelView are obtained using functions dependent on the appropriate detector voltages in the RF Chassis. The coefficients of these functions are determined at the factory and are entered on the appropriate "RF Klystron Constants Screens." See Section 5.1.2 and 5.1.3 for explanations of how to calibrate the RF Chassis detectors and how to obtain the constants used for the functions.

Table 3-6 identifies which box on the RF Klystron Constants Screens each of the constants should be entered in.

Table 3-6. Identification of Constant Entry Boxes for the RF Klystron Constants Screens

RF Detector	Equation for RF Power	C	C exponent	D	D exponent	E	E exponent
Klystron Input Forward	Watts $=C+D*V_D+E*V_D^2$	F3	F11	F4	F12	F5	F13
Klystron Input Reflected	Watts $=C+D*V_D+E*V_D^2$	F6	F14	F7	F15	F8	F16
Klystron Output Forward	Watts $=C+D*V_D+E*V_D^2$	F3	F11	F4	F12	F5	F13
Klystron Output Reflected	Watts $=C+D*V_D+E*V_D^2$	F6	F14	F7	F15	F8	F16



Figure 3-21. PanelView Klystron Input Constants Screen.



Figure 3-22. PanelView Klystron Output Constants Screen.

### 3.1.4 Shutdown

Shutdown can be accomplished by the operator in a number of ways (see Figure 3-1). The PLC logic and the hardwired interlock system prevents damage to equipment and provides personnel safety regardless of how the system is shut down, but unless the equipment is to be completely shut down (including opening the main facility breaker, feeding the Transmitter), it is recommended that the operator set the system in either the “Off” or “Filament Off” modes. If RF power is not needed for a significant time, but it is desired to leave the filament power on, place the Transmitter in the “OFF” Mode.

To transfer to “Off” press the “Off” function key, F7. The RF Amplifier Chassis, both Magnet Power Supplies and the Cooling Structure klystron window blower should shut off. If desired CB2, CB11 & CB12 may be opened, but they must be closed again before the Transmitter can be brought to the “Standby” Mode.

To transfer to “Filament Off” press the “Filament Off” function key, F6. The Filament Power Supply, RF Amplifier Chassis, both Magnet Power Supplies and the Cooling Structure klystron window blower should shut off. If desired all, breakers except CB1, CB3 & CB80 may be opened, but they all must be closed again before the Transmitter can be brought to the “Ready for High Voltage” or “Standby” Mode again.

If the operator pushes “Standby” when in “Ready for High Voltage,” the crowbar will not be triggered but the “Ready for High Voltage” optical signal to the klystron beam power supply will be removed. If no faults have occurred during this time, the “Ready for High Voltage” will be immediately and automatically restored.

Obviously, pressing the Emergency Off button removes power from all parts of the Transmitter (except for the AC Distribution Chassis, the half of the Dog House into which the 208 VAC power has been routed by the user and the power cable between the two, M3553000293).

For a detailed guide to starting up again refer to Figure 2-16.

### 3.1.5 Magnet Power Supplies

The Magnet Power Supplies are single-phase full bridge switching converters with a high frequency rectifier output stage. The DC for the switching bridge is obtained from the 208 VAC lines via a full bridge 60 Hz rectifier. Power Ten is the manufacturer.

The power is turned on by engaging the rocker switch on the front panel. The power supply may be set for current or voltage control. For current control turn the current control knob fully counterclockwise and the voltage control knob fully clockwise before turning the power supply on. Then, slowly advance the current control knob clockwise until the current meter reads the desired amount.

The voltage trip point may be adjusted by pressing the little “READ” button and adjusting the “SET OVERVOLTAGE” recessed screw until the voltmeter reads the desired trip point.

The “V MODE” (“I MODE”) indicator indicates when the power supply is in the voltage (current) control mode. The “OVERVOLT” indicator indicates when the power supply has tripped because of an over-voltage. If a trip occurs it latches and can be cleared by cycling the rocker switch. The “FAULT” indicator indicates that a bias supply failure, converter failure or thermal failure has occurred. If a fault occurs the power supply should be taken out of service.

### **3.1.6 Filament Power Supply**

The Filament Power Supply is a current controlled single-phase switching inverter. The DC for the inverter is obtained from the 120 VAC lines via a full bridge 60 Hz rectifier. California Instruments is the manufacturer. The power supply is completely controlled by the PLC.

The power is turned on by engaging the rocker switch on the front panel. The over-temperature indicator indicates either an over-temperature, output open-circuit condition, excessive load (indicating an over-voltage), low internal amplifier gain, internal amplifier fault or internal DC power supply fault.

Because the power supply is a current source any open circuit or high resistance in its output will cause it to trip. If the product of the current set point (entered on the PanelView) and the load resistance exceeds about 135 volts the power supply will trip. After restoring the continuity of the output circuit or reducing the load resistance the rocker switch may be cycled and the power supply should operate again.

### **3.1.7 Vac-Ion Power Supply**

This is a Cockcroft-Walton high voltage multiplier power supply energized by a single phase, square wave switching inverter. The manufacturer is Duniway Stockroom Corporation. All controls are accomplished from the front panel of the power supply itself.

Please refer to the operating manual in Appendix C for instructions on how to perform a preliminary setup. The power supply has had a preliminary setup at Titan and should operate satisfactory after being connected to the klystron pump.

#### **Summary of Vac-Ion Power Supply Operating Procedure:**

1. Turn the POWER switch on the front panel to ON. No warm-up period is required.
2. When it is suspected or observed that the roughing system has reached its base pressure, the ion pump starting cycle can be started. Note the maximum recommended operating pressures for various pump sizes listed in Table 3-7.

3. Push the High Voltage switch and hold for two seconds. The High Voltage ON LED will be activated and the High Voltage display will show the voltage. The voltage will ramp up to the Maximum Voltage designated in the set-up procedure (or to some lower value determined by the load represented by higher pressure in the ion pump.) The Current and Pressure displays will remain off until several seconds have elapsed (to avoid displaying erroneous transient start up values).

Table 3-7. Ion-Pump Power Supply Maximum Operating Pressures.

Pump Rating (l/s)	Max. Operating Pressure (torr)
400/500	$5 \times 10^{-7}$
220/270	$5 \times 10^{-6}$
110/140	$5 \times 10^{-6}$
60	$5 \times 10^{-6}$
30	$5 \times 10^{-5}$
20	$5 \times 10^{-5}$
8	$5 \times 10^{-4} + \text{Start}^*$
2	$5 \times 10^{-3} + \text{Start}^*$
Mini	$5 \times 10^{-3} + \text{Start}^*$

\*Table Note: With a sputter ion pump, a modest rise in pressure is normal during the initial START. This is caused by heating of the pump components and is beneficial in outgassing the elements for later operation in the NORMAL mode.

4. When the initial voltage (at maximum or rising), current (falling) and pressure (falling) are observed to be improving, close the roughing valve. If the voltage falls (meaning that current and therefore pressure is rising), reopen the roughing valve. If the voltage increases or remains constant (pressure is decreasing or "holding"), leave the roughing valve closed.
5. Maximum Current (Imax) Operation: In operation, if the pump current rises to 6 milliamps, I<sub>max</sub>, it automatically begins limiting power by incrementally reducing the high voltage applied to the ion pump. This incremental voltage reduction continues until the ion pump current stays below the I<sub>max</sub> setting. If the ion pump current remains at or near the I<sub>max</sub> setting for extended periods, it goes into a cool-down mode (below).
6. Cool-Down Mode: If the ion pump current remains at or near the maximum current (I<sub>max</sub>) setting for a period of 10 minutes, the 741-TITAN automatically shuts OFF the high voltage to allow the ion pump to cool down. The high voltage stays off for 5 minutes, then comes back on. This cyclical process continues (10 minutes ON - 5 minutes OFF) for 5 cycles if the ion pump current stays at or near I<sub>max</sub>. If the ion pump current goes significantly below I<sub>max</sub> at any time during this process, the I<sub>max</sub>/Cool-Down Mode will be re-started at the beginning. If the full 5 cycles are completed without significant ion pump current reduction, the 741-TITAN automatically goes into shut down mode (below). A series of 'beeps' is emitted when the cool-down mode or shut down mode is commenced. The display shows "cdX" when the voltage goes off, where X



is the cool-down cycle number, between 1 and 5. The unit emits X beeps when entering a cool-down cycle.

7. Shut-Down Mode: If the 741-TITAN goes through the full cool-down cycle, it goes into shut down mode. The high voltage is turned OFF, a 5 second 'beep' is emitted and the display shows "sd." In addition, if the high voltage output is shorted to ground, due to malfunction of the ion pump, cable or connector, the 741-TITAN will enter shut down mode after 30 seconds have elapsed. The high voltage turns OFF, a 5 second 'beep' is emitted and "sd" is displayed. To recover normal operation from shut down, resolve the situation that led to shut down and press the HV button on the front panel for 2 seconds.
8. Defeating Cool-Down/Shut-Down Modes: Operation of the Cool-Down and Shut Down Modes can be accomplished by changing the internal DIP-switch settings. See Section IV-D.

### **Vac-Ion Power Supply Normal Mode Operation:**

Operation in the NORMAL mode is simple and automatic. As the pressure and current fall, the operating voltage approaches the open circuit value for the control unit; and the current is approximately proportional to pressure over a wide range of pressures. Pressure at the pump inlet flange may be read directly on the "pressure" display of the front panel. (This assumes that the pump size in the selection mode has been made properly during set up.) Alternately, if the current vs. pressure relationship is known for the pump in use, current may be read directly and converted into a pressure reading.

#### **3.1.8 RF Amplifier Chassis**

The RF Amplifier is located in the RF Chassis, whose block diagram is shown in Figure 3-23 along with detectors, sampling ports and a circulator to protect the amplifier against output mismatch. AR/Kalmus is the power supply manufacturer. Power is applied by closing the rocker switch on the front panel.

Over-temperature protection is provided that inhibits amplifier operation when the temperature limit is exceeded. The service required indicator indicates that one or both of the two internal fans has failed, that the fan filter needs cleaning, or that one of the two, parallel diode OR-ed, 28 volt internal power supplies has failed.

#### **3.2 REMOTE INTERFACE**

The PLC may be connected to a remote interface, from which partial control of the Transmitter may be implemented and to which all status and measured values in the PLC are made available. The connection is made via a category 5 data cable between the remote controller and the PLC's CPU.

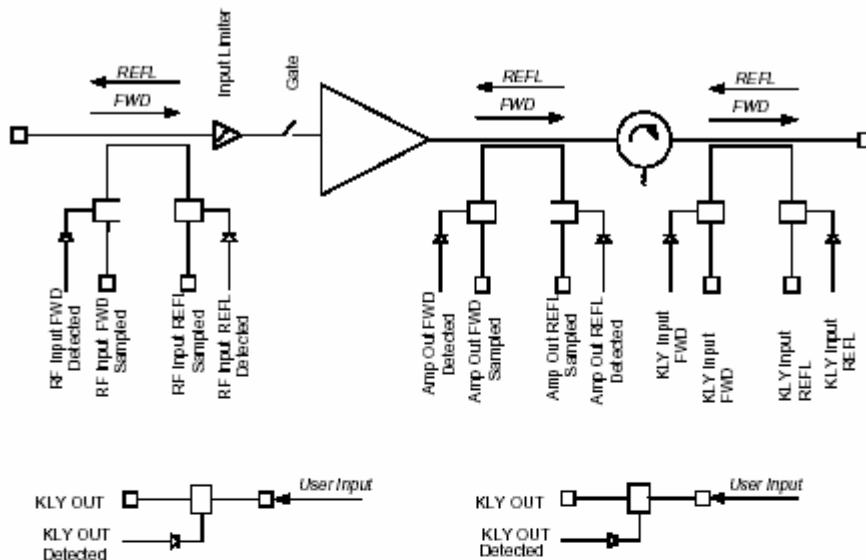


Figure 3-23. RF Chassis, Simplified Block Diagram.

### 3.2.1 PLC Remote Communication Setup

See Section 2.3.1.2.

### 3.2.2 Monitoring and Control from Remote Interface

The current status of all interlocks will be available from the Remote Interface, as well as the fault log (without time stamps). All real time monitored values such as current, voltage RF Power, temperatures, flow rates dissipated power, etc. will also be available, as well as “Frozen” screens.

There will be limited control from the Remote Interface. “Reset” may be performed, which will reset any faults or interlocks, as long as they are no longer faulted. For example, if someone has removed the grounding stick from the High Voltage Enclosure and not replaced it a “Reset” command will not reset the grounding stick fault.

Mode changes may also be made if the appropriate interlocks for the new mode are all satisfied. See Tables 2-1, 2-2 and 2-3 of Section 2.4.

No other control functions have been made available to the Remote Interface, including changing limits or constants. These functions must be done from the front panel.

### **3.3 COOLING STRUCTURE**

#### **3.3.1 Pressure Blower Outlet Damper Valve**

Power will be applied to the Pressure Blower after the Cooling Structure breaker CB5 is closed and the Transmitter enters "Standby." A manual damper valve is located on the outlet of the blower. This valve may be used to vary the air flow rate to the klystron window.

#### **3.3.2 Klystron Window Air Flow Switch**

The klystron low airflow interlock switch is located in the Air Stream Sensor Housing (see drawing M355300265), at the end of the air flow duct near the klystron window. The switch threshold may be adjusted with the small recessed screw head, located at the end of the switch housing. When the LED, in the end of the switch housing, is extinguished, the interlock has been tripped. Clockwise adjustments set the trip threshold at higher air flows.

#### **3.3.3 Throttling Valves**

The throttling valves are located on the inlet side of the cooling structure and the shutoff valves are on the outlet side of the cooling structure, (see Figure 2-3). Both the shutoff and throttling valves can be closed when a heat load is disconnected or being changed, so that the facility water does not have to be shut off.

The throttling valves can be used by themselves to vary the flow rate to a single heat load. They allow fine adjustments to the flow and balancing of the flow between heat loads.